EUROMECH Colloquium 573

"Coupling and Nonlinear interactions in Rotating Machinery"

25 – 27 August, 2015, Lyon, France

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Rotating machines hold a central place in today's transport and energy issues concerning economy and safety aspects. Their mechanical design requires multidisciplinar modelling with non-linear coupled dynamics phenomena. Thus, the purpose of this colloquium was to promote exchange in the rotor dynamics community around their most advanced research in coupling and nonlinear dynamics. The originality here is in the merging, in a same place, of people usually associated with closely-delimited themes and spread in big congresses (such as ASME TurboExpo) without clear opportunity to discuss similarities in their approaches and consider crossed-fertilization.
People involved in Euromech 573 are mainly specialized in bearings and seal devices problems, quasi-cyclic structures robust modelling, interaction between rotating structure with a casing or with surrounding fluid. All use quite similar methods to deal with non-linear vibrations with limit cycle or stability issues but in different multiphysic contexts.
There were altogether 26 registered participants but many more people attended one or more sessions due to intended close proximity with national Congrès Français de Mécanique, CFM 2015. There were 21 presentations mixing junior and senior researchers, among them 2 keynote lectures. Namely G. Kerschen (Liège) and D. Ewins (Bristol, registered in CFM but assiduous in Euromech) offered very appreciated keynotes, L. Panning von Scheidt (Hannover), W. Seemann (Karlsruhe), A. Combescure (Lyon), A. Lucas (Total, Pau) contributed also, with many others, please see the list of participants and full program. More importantly, a lot of time has been dedicated to informal discussions between the participants.
Reoccuring issues addressed in the talks and discussed were:

- Interaction modelling
Fluid-structure interaction and structure-structure contact were most investigated, with different levels of sophistication in bearings or between blades and casing. Thin films of lubricant (Rebufa etal) or air (Baum etal) lead to Reynolds-like equations in quasi-analytical frames but enriched analytical models take acoustic effects into account (Andreev etal). Cavitation issues or acoustic resonance draw limits between validity domains that have been discussed. Localized contact modelling present remarkably common approaches including harmonic balance method and alternate frequency-time strategies to deal with the contacting elements (Salles etal, Epureanu etal, Panning von Scheidt etal) in spite of different post-processing. The most elaborated model presented here dealt with both contact and fluid interactions for brushless seals analyses (Pugachev etal) with very interesting prospects for more complicated flows.

- Multiscale modelling
Many works separate space scales to better capture significant tendencies. Modulated waves, called solitons, imported from optics and solid mechanics, have been used (Grolet etal), and remarked as alternative to harmonic balance method to detect localization in cyclic symmetry structure. In a different context, textured patterns in bearings (J. Rebufa), homogenization technique has been used to get simplified constitutive Reynolds-like laws for the bearings, giving ideas for the elaboration of meta-models stemming from expensive but generic FEM-CFD coupled computations.

- Reduced order modelling
The need for computationally "light" models is a recurring theme of discussions. Including interaction non linearity generates heavy calculations when extending them from research laboratory to industrial design offices: in complicated multiscale frames, one seeks for robustness and many simulation runs, with different parameters draws; even for identification purposes (Kerschen) or active control (Becker etal) light

models are required. Concerning time scales, harmonic balance approaches can be seen as a “basic” way to reduce models and it is widely used, as said before (Salles etal, Baguet etal). They have been used here in parametric studies to track stability conditions according to friction coefficient by continuation strategies for example (Baguet etal), or in a context of non-linear normal modes calculation (Kerschen). A non-parametric strategy offers alternative ways of taking alea into account, and more specifically here mistuning effects (Capiez-Lernout etal). A workbench on common test-cases has been discussed to compare strategies and test their effectiveness from industrial point of view.

- Code coupling issues

It is widely accepted that multiphysics phenomena are difficult to model, in industrial context, because different codes based must be coupled. For “simple” problems, monolithic approaches are programmed (Rebufa etal, Andreev etal). But for more versatile computations, rotor-dynamics community resorts to iterative approaches, when mixing solid contact and fluid-interaction difficulties for example (Pugatchev etal). A very promising approach couples both harmonic balance for solid FEM modelling and its CFD equivalent, the Time Spectral method (Cadel etal) in a weak coupling context. Non - intrusivity is also reached by a method, tested for failure transient analyses, that couples Smooth Particle Hydrodynamics (SPH) and FEM (Combescure etal). The quest for the best compromise in coupling techniques is still an open race and, here also, rotor-dynamics is a fertile investigation field.

- Need for experiments

At the very end, in such complex contexts, any new model requires experimental validation. Few participants showed such works except a test bed dedicated to bearings testing (J. Rebufa) and spectacular identification by Kerschen. It is a prospect, for a future meeting to give a larger place to crossed numericalexperimental works: industrial works by Gelin etal showed how much the dialog between experimental investigation and simulation is fruitful to track rotating machines failures for example.

From above list it becomes clear that many questions are far from being solved and that the domain, with its specificities, is still on quest for “good modelling practices”. The community agreed that the meeting provoked fruitful brainstorming and opened ways to further collaborations. A new meeting two years from Euromech 573 is wished by the participants, in 2017 in a place that is still to be chosen.

We thank Euromech for making the meeting possible and for all the financial and organization support.

Ecully, April 4rd, 2016

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